Modeling laser wakefield accelerators in a Lorentz boosted frame

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Modeling of laser-plasma wakefield accelerators in an optimal frame of reference is shown to produce 4-6 orders of magnitude speed-up in calculations from first principles of stages in the 10 GeV-1 TeV energy range, in agreement with the maximum obtainable speedups that are predicted by theory. Obtaining these speedups requires mitigation of a high-frequency instability that otherwise limit effectiveness using a mix of established and novel numerical techniques, and solutions for handling data input and output in a relativistically boosted frame of reference. Using these techniques, agreement at the percentage level is demonstrated between simulations using different frames of reference, with speedups reaching two orders of magnitude, for a 0.1 GeV class stages. The method is then shown to enable direct, efficient full-scale modeling of deeply depleted laser-plasma stages in the 10 GeV-1 TeV range, verifying the scaling of plasma accelerators to very high energies, providing designs for experiments on new lasers such as BELLA.

Work supported by US-DOE Contracts DE-AC02-05CH11231 and DE-AC52-07NA27344, and US-DOE SciDAC program ComPASS. Used resources of NERSC and LBNL cluster Lawrencium, supported by US-DOE Contract DE-AC02-05CH11231.